ARTICLE IN PRESS

Journal of Transport & Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

Bicycle-sharing system socio-spatial inequalities in Brazil

Ana Clara Duran[a,*], Esther Anaya-Boig[b], Joshua Daniel Shake[c], Leandro Martin Totaro Garcia[d], Leandro Fórnias Machado de Rezende[e], Thiago Hérick de Sá[a]

[a] Center for Epidemiological Studies in Nutrition and Health, University of Sao Paulo, Avenida Doutor Arnaldo, 715, Sao Paulo, SP 01246-904, Brazil
[b] Centre for Environmental Policy, Imperial College London, South Kensington Campus, London SW7 2AZ, United Kingdom
[c] Center for Metropolitan Studies, University of Sao Paulo/Brazilian Center of Analysis and Planning, Av. Prof. Luciano Gualberto, 315 - Salas 116B / 2, Sao Paulo, SP 05508-900, Brazil
[d] National School of Public Health, Oswaldo Cruz Foundation, Rua Leopoldo Bulhões, 1480, Rio de Janeiro, RJ 21041-210, Brazil
[e] Departamento de Medicina Preventiva, Faculdade de Medicina FMUSP, Universidade de Sao Paulo, Sao Paulo, SP 01246-903, Brazil

1. Introduction

Bicycle use can contribute to curbing high worldwide levels of physical inactivity, which is responsible for 6% to 10% of the burden of non-communicable diseases, such as Type 2 diabetes, coronary heart disease, and breast and colon cancers (Lee et al., 2012). The benefits also seem to outweigh the risks (i.e. exposure to air pollution (de Hartog et al., 2010; Tainio et al., 2016; Woodcock et al., 2014)). Such benefits make bicycling a key component in improving population health, reducing environmental hazards (e.g., air and noise pollution), and addressing climate change in urban areas (Handy et al., 2014; Hunter et al., 2017). The promotion of bicycling as part of sustainable transport systems has recently been explicitly stated in the international policy paper "New Urban Agenda" (United Nations, 2017).

Bicycle-sharing systems have been used to promote bicycling as a viable means of transport in cities. After a sharp increase in recent years, almost 1200 cities worldwide have bicycle-sharing systems (Meddin, 2017). In Brazil, bicycle-sharing systems have expanded in the last decade due to public-private partnerships promoted by municipalities (Gauthier et al., 2013). Bicycle-sharing systems can provide valuable data, as detailed information on distance, location, and duration of each of the trips can often be obtained for each user (Romanillos et al., 2016). These datasets collect detailed input on the trips which can be linked to the profile of the users, allowing, for instance, for the evaluation of specific health impact outcomes (Rojas-Rueda et al., 2011; Woodcock et al., 2014), with variables for which private bicycling data are either unavailable or incomplete.

Initial evidence on bicycle-sharing systems from high-income countries shows that they seem to attract a specific profile of users in terms of gender (males), ethnicity (white), and work status (employed) (Woodcock et al., 2014). The pool of bicycle-sharing system users also seems to be younger, richer, and more highly educated than the general population where these systems are located (Fishman et al., 2014; Shaheen et al., 2013).

These demographic discrepancies are often exacerbated by the unequal distribution of the stations and covered areas (Clark and Curl, 2016; Ogilvie and Goodman, 2012; Ricci, 2015). Such spatial distribution has been attributed to economic and political goals that favor central and densely populated areas of the city in the initial implementation to maximize the use of the stations. However, such allocation of resources can lead to unequal access to the system (Gauthier et al., 2013; Goodman and Cheshire, 2014). Examples of economic and political goals ruling the implementation of the systems are: managing tourism (in some cases encouraging access, in others restricting it), advertising deals with private entities (such as banks and private companies that sponsor the systems) (Duarte, 2016), public visibility of the actions, and contribution to the image of the city as sustainable or "green" (Ricci, 2015). Improving the

* Corresponding author.
E-mail addresses: anaduran@usp.br (A.C. Duran), e.anaya14@imperial.ac.uk (E. Anaya-Boig), jdshake@umich.edu (J.D. Shake), leandromtg@gmail.com (L.M.T. Garcia), lerezende@usp.br (L.F.M.d. Rezende), thiagoherickdesa@gmail.com (T. Hérick de Sá).

https://doi.org/10.1016/j.jth.2017.12.011
Received 2 June 2017; Received in revised form 21 December 2017; Accepted 29 December 2017
2214-1405/ © 2018 Elsevier Ltd. All rights reserved.

Please cite this article as: Duran, A.C., Journal of Transport & Health (2018), https://doi.org/10.1016/j.jth.2017.12.011

connection of bicycle-sharing systems with other modes of public transportation is often not among the main goals of these systems. A better integration of different modes of transportation provides access to users who need to cover longer distances on their daily commutes and/or live far from bicycle-sharing stations.

In Brazil, despite the proliferation of bicycle-sharing systems in large cities, little information is available on where they are located, as well as the technical and political decisions governing their planning and implementation, and to what extent they can contribute with social and spatial inequalities. We thus assessed whether bicycle-sharing systems located in large Brazilian cities are unequally distributed, and performed a document analysis of the planning and implementation process in one of the study cities to understand to what extent this process may contribute to an unequal social and geographic distribution of these systems.

2. Material and methods

We employed a mixed-methods approach to assess the spatial and social inequalities in Brazilian bicycle-sharing systems (Creswell and Clark, 2011). Data were drawn from a survey with bicycle-sharing systems users across five large Brazilian cities and a document analysis of the largest bicycle-sharing system in Brazil.

2.1. Users' characteristics and social and spatial distribution

Using a cross-sectional design, we included in the study only Brazilian capital cities for which bicycle-sharing system and users' characteristics were available: Porto Alegre, Recife, Salvador, Sao Paulo, and Rio de Janeiro. We obtained information on bicycle-sharing systems' users from intercept surveys conducted by the Brazilian Centre of Analysis and Planning (CEBRAP) between June and December of 2014 (Porto Alegre: June; Recife: July - August; Salvador: September - October; Sao Paulo and Rio de Janeiro: November - December).

Secondly, we gathered information on the location of bicycle-sharing stations using the Bike-Sharing World Map (DeMaio and Meddin, 2017). Information on the bicycle-sharing systems partners, subscription rules, and costs were obtained from each management company website and confirmed by phone in July 2016. The geocoded locations of the systems' stations and the number of slots in each station were available at the bike share schemes websites' source code. The source codes were copied to the software Notepad + + 6.7.9.2 in July 8th, 2016, and the information was extracted for each city using a script implemented in Stata 13.1. The outputs from the script were transferred to a geographic information system software. We created the catchment area for each system using buffers of 500 m around each station, which corresponds to the average distance between pairs of nearest neighbor stations in the study sites (465 m) using ArcGIS Desktop 10.4. We used Euclidean distance to calculate the nearest neighbor distance between bicycle-sharing stations QGIS Geographic Information System (QGIS Development Team, 2017).

2.1.1. Statistical analysis

Firstly, we described the characteristics of bicycle-sharing systems catchment areas in each city and compared this with citywide information available at the 2010 Brazilian Census (IBGE, 2016). We compared citywide information on the size of the population covered by each system's catchment area, percent of the population covered by this same catchment area, mean income of the head of the household, and percent of the population who self-declared to be white in each catchment area. Finally, we divided the information on the mean income of the head of the household in the system catchment area by the same information in the entire city to create an income ratio variable.

Secondly, we described users' characteristics by socioeconomic variables: sex, age (10 – 19, 20 – 29, 30 – 39, 40 – 49, 50 – 59, and ≥ 60 years), educational level (elementary school or less, middle school, high school, and college or more), and monthly household income (≤ 2, 2 – 5, 6 – 10, > 10 minimum wages). As of July 2014, the Brazilian minimum wage was R$ 724.00 or US$ 326.00. We then compared users' characteristics with 2010 Brazilian Census data (IBGE, 2016) for each city. Variables included the percentage of males, age, educational level, and mean household income.

To assess whether there were socioeconomic and spatial inequalities in the access to bicycle-sharing systems, we averaged data on the mean income of the head of the household, estimated the total population, the percentage of white residents, and the area covered by each bicycle-sharing system catchment area. We then compared these characteristics with the same variables for the entire municipality. Data were gathered from the most recent Brazilian Census (2010) (IBGE, 2016).

We conducted a sensitivity analysis using buffers of 1000 m around each station to create alternative catchment areas for each system. We decided to test whether a larger distance, which corresponds to approximately 10 minutes of reasonable walking for transportation distance and time (Watson et al., 2015), would produce different results.

Stata 13.1, ArcGIS 10.4, and QGIS Geographic Information System (QGIS Development Team, 2017) were used to perform the analyses.

2.2. Case study

We then conducted a document analysis for the City of Sao Paulo to highlight the decision-making processes behind the spatial outcomes and locations of the bicycle-sharing systems identified in the quantitative portion of this article and to understand to what extent the planning and implementation of this system may have contributed with an unequal access to the stations. We used a critical case study format, following Ragin and Amoroso's (2010) methods and because of the unbounded interfaces between phenomenon and context in this example (Yin, 2008). We thus attempted to understand the complexities and intricacies of the layering of and planning of systems behind the various bicycle-sharing programs in São Paulo. Specifically, it took the format of a linear-analytic case study emphasizing exploratory and descriptive purposes (Yin, 2008). Additionally, we employed an actor-centered approach highlighting how urban spaces are shaped by various internal and external forces of change at different scales (Markusen, 2004; Olds, 2002; Shatkin, 2008; Yeoh, 1999); and emphasized historicized trajectories and contexts of urban policy development (Abu-Lughod, 1999; Shatkin, 2008).

We chose the city Sao Paulo because it houses the largest bicycle-sharing system (combining BikeSampa and CicloSampa) in the country, and information on how the bicycle-sharing system was implemented was available in public records. We examined the websites of Sao Paulo's Secretariat of Urban Planning and Development, Transportation Secretariat, and the City of Sao Paulo websites, online public records on the City of Sao Paulo Diario Oficial, and the bicycle-sharing programs, management consortiums, and companies that are part of the consortium, using a keyword search (bicycle-sharing systems, bicycle, and the names of specific programs and companies involved in the implementation process). This was supplemented by searches of laws, contracts, and regulations mentioned in cross-references contained in the first set of resulting documents. These searches occurred every ten weeks between January and October 2016 to account for any updates and changes to the contracts and regulations. Materials were coded based on thematic subject areas, including planning processes, contractual arrangements, and collaboration between various cycling and other transportation systems (Weiss, 1995). Initially, we read the documents deemed relevant upon first review, eliminating those that did not actually pertain to the bicycle-sharing systems. Secondly, we reviewed the documents to identify the thematic areas and sort the data. We then examined the documents again for the final coding. Finally, findings were triangulated across the various types of data sources examined (Groat and Wang, 2002).

3. Results

3.1. Brief description of the cities

Porto Alegre is a Southern city and has around 1.4 million inhabitants, the highest mean monthly household income and lowest GINI coefficient (0.614) of the studied cities (IBGE, 2016). Recife and Salvador, located in the Brazilian Northeastern region, are the poorest among study cities. Recife is also the most unequal study city (Recife's GINI coefficient = 0.689, Salvador = 0.645). Sao Paulo and Rio de Janeiro, located in the Brazilian Southeast region, are the largest and among the richest cities in Brazil. Income inequality is, however high across the country (The World Bank, 2016), with GINI coefficients reaching 0.645 and 0.639 in Sao Paulo and Rio de Janeiro, respectively.

Despite socioeconomic differences across study cities, almost 100% of their populations live in urban settings (IBGE, 2016). Table 1 presents the characteristics of each city.

3.2. Characteristics of the bicycle-sharing systems

All cities have *Itaú Bank* as the main private sponsor and *Serttel/Samba* as the private operator of the bicycle-sharing systems. Sao Paulo is the only city where two independent systems coexist. Aside from an *Itaú Bank* sponsored system, a second system known as CicloSampa is sponsored by *Bradesco Bank*. Registration is needed to use any of the systems. In all bicycle-sharing systems, a credit card is required for an online registration. There is no annual fee and all systems have the first hour free of charge and R$ 5.00 (US$ 1.55 as of January 2017) are charged for every additional hour of use (except for CicloSampa, in which the first 30 minutes are free and then R$ 5.00 are charged for every additional 30 minutes). During the same period, bus fares were around R$ 3.80 (US$ 1.17) across all cities.

3.3. Social and spatial distribution

Fig. 1a-e depict social and spatial inequalities in the access of bicycle-sharing systems. Catchment areas based on 500-m buffers around bicycle-sharing stations covered relatively small geographic portions of the cities, varying from 7.9 to 24.7%, encompassing 6.2 to 18.3% of the cities' population (Table 1).

In all cities, most of the bicycle-sharing stations are in high-income neighborhoods, which in coastal cities (Recife, Rio de Janeiro and Salvador) are found along the seashore. Unequal access to these systems in terms of income is noteworthy: the mean income of the head of the household in the areas served by the bicycle-sharing systems was 1.6 to 2.3 times the cities' mean income of the head of the household. Absolute differences between catchment areas and city-level mean income varied from R$ 1,169 in Sao Paulo to R$ 2,601 in Salvador (Table 1). Analysis using a larger catchment area (1000-m buffers around stations) showed similar results.

Areas served by bicycle-sharing systems also had a higher percentage of white residents when compared with citywide figures across all five sites. For instance, in Salvador, where 18.9% of the population is white, the percentage of white residents in the city's bicycle-sharing system catchment area was almost twice as higher (35.6%).

3.4. Users' characteristics

Bicycle-sharing systems users' characteristics differ, in general, from the observed demographics of the entire city (Table 2). For instance, there are more men than women in 4 of the 5 cities (not in Porto Alegre). In terms of educational level, bicycle-sharing users have an overwhelmingly higher attainment than each city general population. Despite lower educated individuals (less than high

Table 1
Bicycle-sharing system characteristics and citywide characteristics in selected Brazilian state capitals.

	Citywide data[a]				Bicycle-sharing system catchment area						
	Population (millions)	Mean income of the head of the household (R$)[b]	White pop. (%)	Area[c] (km^2)	Name (slots / stations)	Date of system's implementation	% city's population covered	% city's area covered	Mean income of the head of the household (R$)[a,b]	White pop. (%)	Income ratio[d]
Porto Alegre	1.41	2421.76	79.2	160.70	BikePoA (342 / 28)	Sep 2012	6.28	7.95	3872.25	90.70	1.60
Recife	1.54	1791.89	41.42	121.10	BikePE (960/ 79)	May 2013	16.58	24.71	3492.59	57.80	1.95
Rio de Janeiro	6.32	2070.17	51.18	557.30	BikeRio (3102 / 248)	Dec 2011	18.28	12.86	4671.83	74.37	2.26
Salvador	2.68	1490.66	18.9	159.30	BikeSalvador (460 / 38)	Jul 2013	13.49	13.02	3078.38	35.63	2.07
São Paulo	11.25	2089.52	60.64	968.30	BikeSampa (2996 / 249)	May 2012	12.22	9.94	3258.55	81.89	1.56
					CicloSampa (200 / 16)	Dec 2013					

[a] Based on the Brazilian Institute of Geography and Statistics 2010s census.
[b] As of Jul 2010, R$ 1.00 = US$ 0.56.
[c] Area includes urbanized area as measured by satellite images (Embrapa, 2016).
[d] Mean income of the head of the household in the system catchment area / Citywide mean income of the head of the household.

ARTICLE IN PRESS

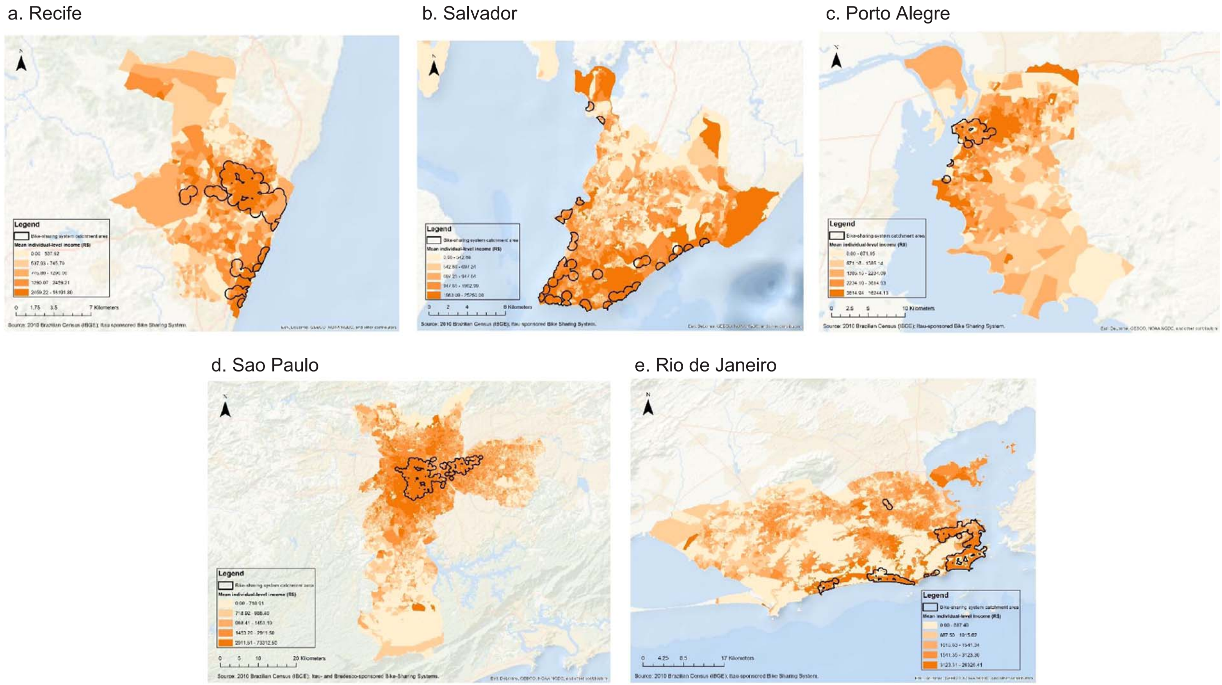

Fig. 1.

Table 2
Characteristics of bicycle-sharing system users in selected Brazilian state capitals (2014), compared with citywide population characteristics (2010).

Characteristics	Porto Alegre (n = 317)		Recife (n = 370)		Rio de Janeiro (n = 503)		Salvador (n = 318)		Sao Paulo (n = 455)	
	%	%Pop[a]	%	%Pop[a]	%	%Pop[a]	%	%Pop[a]	%	%Pop[a]
Sex										
Women	59.9	54.2	47.0	54.6	41.4	53.7	28.0	53.9	26.3	53.2
Men	40.1	45.8	53.0	45.4	58.7	46.3	72.0	46.1	73.7	46.8
Age (years)										
10 – 19	5.1	16.4	16.2	18.4	4.5	16.7	20.6	18.2	11.7	17.5
20 – 29	32.5	19.9	45.5	21.0	33.2	19.1	42.1	23.0	44.7	21.1
30 – 39	34.7	17.3	30.0	18.7	30.4	17.9	25.6	20.6	30.0	19.4
40 – 49	21.5	15.4	9.7	16.3	20.1	15.8	8.5	16.2	7.9	15.9
50 – 59	4.3	14.0	4.3	12.0	8.4	13.6	2.9	11.4	5.7	12.4
≥ 60	1.9	17.0	0.3	13.6	3.4	16.9	0.3	10.6	–	13.7
Educational level										
Elementary school or less	0.6	31.8	–	39.8	–	34.3	2.9	37.5	0.7	38.1
Middle school	10.1	17.4	6.8	16.6	6.0	18.4	10.8	17.0	5.6	18.6
High school	74.5	30.6	73.8	29.2	45.3	30.7	58.5	34.4	40.4	27.0
College or more	14.8	20.2	19.4	14.4	49.7	16.6	27.8	11.1	53.3	16.3
Monthly household income (minimum wages)[b]										
≤ 2	13.5	18.7	35.4	38.5	1.4	23.7	34.5	39.1	6.5	20.4
2 – 5	52.0	32.6	38.1	30.4	29.9	34.2	41.3	32.9	28.0	34.8
6 – 10	28.8	23.5	19.2	14.4	35.9	20.7	17.4	14.8	32.2	22.6
> 10	5.7	25.2	7.3	16.7	32.8	21.4	6.8	13.2	33.3	22.2

Monthly household income had the lowest response rate (Porto Alegre: 98%, Recife: 79%, Salvador: 67%, Sao Paulo: 84%, Rio de Janeiro: 88%). Otherwise, the lowest response rate was 97% (age, Sao Paulo).

[a] Proportion in the city's population, based on the Brazilian 2010 Census data.

[b] As of Jul 2010, Brazilian national minimum wage = R$ 510.00 or US$ 286.00. As of Jul 2014, 1 minimum wage = R$ 724.00 or US$ 326.00.

school) representing 30 to 40% of the population, in four cities (Porto Alegre, Recife, Sao Paulo, and Rio de Janeiro) such group represents less than 1% of the users. In Sao Paulo, more than half of the users have a college degree, while the city's figure only reaches 16% of the population. Porto Alegre is again an exception, as users have lower education level than the city general population.

Even though the mean income of the head of the household in the areas served by the bicycle-sharing systems was higher than the cities' mean income of the head of the household (Table 1), bicycle-sharing systems' users do not necessarily belong to high-income groups (*i.e.*, monthly household income higher than 10 minimum wages). For instance, in Porto Alegre, Recife, and Salvador, more than 65% of the users earn less than five minimum wages (Table 2).

3.5. Case study of Sao Paulo

3.5.1. Characteristics of bicycle-sharing systems in Sao Paulo

The city of Sao Paulo currently has two active bicycle-sharing systems, along with two non-operative systems: inside the largest university campus in the city and another within a few subway stations. Sao Paulo's first bicycle-sharing system began in 2008 in 10 subway stations, but was suspended in 2012 due to lack of sponsorship received by the *Instituto Parada Vital*, a Non-Governmental Organization that managed the system at the time. This system was reactivated by another management company, FGTV *Produções*, in July 2013, but remained open for less than a month due to structural and management issues.

BikeSampa, the main running system, is sponsored by Itaú Bank, the largest private bank in Brazil and second largest in the country (Banco Central do Brasil, 2015). The system is managed by Mobilicidade/Serttel—a bicycle-sharing and public parking management company with sharing systems in ten other Brazilian cities. At least five of these other systems are also sponsored by Itaú Bank (Mobilize Brasil, 2016). BikeSampa was implemented in 2012 (Mobilize Brasil, 2012) and has a wider spatial reach in comparison to the other running systems in the city, although stations are concentrated in central and high-income areas of the city, as seen in Fig. 1d.

The other bicycle-sharing system, CicloSampa, is sponsored by Bradesco Bank (which also sponsors open street initiatives) and began in 2013 (CicloSampa, 2013; Mobilize Brasil, 2013). Bradesco bank is the second largest private bank in Brazil and fourth largest in the country (Banco Central do Brasil, 2015). It is the only Brazilian system managed by PegBicycle/Trunfo company, and is also highly concentrated in a few high-income and central neighborhoods. However, this system is not integrated with BikeSampa and operate with different payment schemes and mechanisms.

In the Sao Paulo BikeSampa system, no information about transportation planning (i.e., the specific methods employed to determine siting of the stations) was publicly available; rather, contracts merely stipulated the number of stations to be constructed and the number of bicycles to be in the system (Diário Oficial do Estado de São Paulo, 2012). Furthermore, this system did not pass through any forms of public participation and we did not find any information regarding it (Diário Oficial do Estado de São Paulo, 2013).

3.5.2. Contractual conditions of BikeSampa

In early 2015, BikeSampa's contract with the city expired and the city government attempted to open a new contractual public bidding process. Stipulations of this new contract would have expanded the period of free time and added at least 400 new stations throughout the city, as well as additional transparency and oversight measures. This would have included more open data and public access to ridership information (Diário Oficial da Prefeitura de São Paulo, 2015). Additionally, the new public bidding would have allowed for more than one sponsor and consortiums (Diário Oficial da Prefeitura de São Paulo, 2015), a measure that could have foreseen the integration of the two major systems. The bidding system would have also prioritized offers that installed more stations in less time and that would also serve peripheral neighborhoods (Diário Oficial da Prefeitura de São Paulo, 2015). However, contracting officials and representatives of BikeSampa warned that should BikeSampa have not won the renewal, their entire system would be removed and a new system would be created by the winning bidder (Balago, 2015).

This public bidding process was suspended by the municipal audit office later in 2015 due to complaints from two interested businesses (Diário Oficial da Prefeitura de São Paulo, 2015). According to these businesses, the bidding process limited the number of potential bidders because of the expansion project's size, scope, and timeline. Businesses also claimed that it was restrictive in requiring potential bidders to have previous experience managing bicycle-sharing systems of at least 40 stations. Meanwhile, BikeSampa continues to manage the system without a contract, but has suspended the expansion of stations and number of bicycles (Diário Oficial da Cidade de São Paulo, 2015). Thus, the number of stations out of service has grown and the number of available bicycles has decreased, as has also been observed in Recife (Soares, 2016).

3.5.3. Further bidding processes

In January 2016, the municipal government opened a request for proposals for bicycle-sharing systems in the city, which allows for potential management companies to define their own criteria, project size, scope, and timeline, among other factors. Later in 2016, the municipal government passed a law, Integra-Bike, to create a new and expanded system near and within subway stations, train stations, and bus terminals, but until December 2016, it had not yet announced specific plans for its implementation (Diário Oficial da Prefeitura de São Paulo, 2016).

4. Discussion

We assessed whether bicycle-sharing systems in five Brazilian large cities had an unequal social and spatial distribution, and performed a document analysis of the planning and implementation in the municipality of Sao Paulo. We found that bicycle-sharing systems in Brazil do not equally serve the population of the state capitals in which the study was conducted. Only a fraction of the population (6.28%-18.28%) and area (7.9 to 24.7%) of the studied cities are covered by the systems, which are also located in wealthier neighborhoods. We found that the mean income of the areas served by the bicycle-sharing systems was twice the cities' mean income.

Unequal access to bicycle-sharing systems has also been documented in other parts of the world, such as New York, London, Glasgow, Toronto, Chicago and Mexico City (Clark and Curl, 2016; Duarte, 2016; Goodman and Cheshire, 2014; Ogilvie and Goodman, 2012). In Glasgow, for example, only 10–15% of the population has access to bicycle and car sharing stations (Clark and Curl, 2016). In London, "deprived areas" were more likely to be further away from stations, and females and residents in deprived areas were underrepresented among system users in 2012 (Goodman and Cheshire, 2014; Ogilvie and Goodman, 2012).

Although planning guidelines for bicycle-sharing systems suggest that bicycle stations must be in neighborhoods with higher population density (Gauthier et al., 2013; NACTO, 2016; Toole Design Group, 2012), few of them mention specifically the risk of spatial inequalities (Shaheen et al., 2016). In Sao Paulo, we found that bicycle-sharing stations are not only in neighborhoods with higher population densities, but also in wealthier and proportionally whiter neighborhoods. These are also areas with some of the best living conditions in the city, more green space and consequently more pleasant temperatures, lower crime rates (Villaça, 2011), as well as better access to healthy foods and facilities for physical activity (Duran et al., 2013; Jaime et al., 2011).

Bicycle-sharing systems in many of the cities featured in the literature are also linked to advertising contracts with the sponsoring companies (Duarte, 2016). Such contractual arrangements (Ricci, 2015) and the role of advertising (Duarte, 2016) can influence the siting and structuring of bicycle-sharing systems. These arrangements may partially explain the reported spatial limitations, particularly by hindering the expansion to poorer areas (Duarte, 2016). While our study of contractual arrangements focused on Sao Paulo, similar phenomena may occur in other Brazilian cities as the same private partner serves all studied cities. In bicycle-sharing systems, as in other types of public-private partnership arrangements, private sector actors seek returns (including financial, public image improvement, and marketing) from their investments. Public bids for future systems in Sao Paulo recognize these shortcomings and have called for more transparency and better integration with other existing forms of public transportation (Diário Oficial da Prefeitura de São Paulo, 2015). However, none of these have advanced to the planning — much less the implementation — phase (Diário Oficial da Cidade de São Paulo, 2015; Diário Oficial da Prefeitura de São Paulo, 2016). Although expanding the systems to better serve low-income neighborhoods (Ricci, 2015) can help reduce reported inequalities, systems have faced contractual limitations in other settings (Beroud and Anaya, 2012). A more thorough analysis of the role of public agencies in these systems (Shaheen et al., 2016), the models of public-private partnerships (Beroud and Anaya, 2012), and other governance aspects such as participatory processes (Anaya and Castro, 2012) can help address the equity issues found in this article. Bicycle-sharing systems in Brazil primarily target short trips – the initial 30–60 minutes of use are free. Moreover, the location of the stations is not integrated with other modes of public transportation. Recent attempts in Sao Paulo have tried to address the issue of intermodality, but have not yet been implemented (Diário Oficial da Prefeitura de São Paulo, 2016). In Sao Paulo, unclear guidelines in contracts and number of actors involved in transportation system planning made such goal less reachable (Diário Oficial do Estado de São Paulo, 2013, 2012). Taking the Sao Paulo example, the subway and regional train systems are managed by the state government, the bus system is managed by the municipal government, and bicycle-sharing systems are managed by private sector actors (Diário Oficial da Prefeitura de São Paulo, 2016). Such disparate planning makes comprehensive and interconnected systems difficult.

Nonetheless, many of these issues we found in Brazil have been identified around the globe (Beroud and Anaya, 2012; Shaheen et al., 2016). Prohibitive costs for users, stations with inadequate distances between them, poor integration with other transport systems, low levels of geographic and socio-economic dispersion across cities, and management issues between the public and private sectors are some of the issues that have prevented bicycle-sharing systems from reaching their fullest potential. Cities like Seattle – ranked at 24 for bicycle commuting (3.7% of commutes are done by bicycle) among cities above 65,000 inhabitants in the United States (League of American Bicyclists, 2015) –, have even discontinued their systems for some of the above reasons (Small, 2017). As these systems continue to expand and mature, such issues should be confronted to ensure their long-term sustainability, viability, and to increase usership numbers and access.

Policymakers and practitioners should include equality indicators in their evaluation strategies, planning, and technical activities. To ensure parity in access, call for tenders and contractual documents—as well as planning processes—should also address equity (Ricci, 2015). Furthermore, when introduced in certain areas, bicycle policies can generate "bikelash", resistance or hostility towards the presence of cyclists or cycling facilities in the streets (Wild et al., 2017) and the potential gentrification processes should be accounted for (Hoffmann and Lugo, 2014).

The strengths of our paper include the combined analysis of Brazilian state capitals located in different geographic regions of the country, enabling us to study the differences and similarities of the implementation of these systems across cities. Secondly, we analyzed whether spatial and social inequalities were present both in the geographic coverage of the bicycle-sharing systems and in the distribution of the users. Finally, by adding a document analysis of the largest system in the country, we discussed the role of the systems' contractual arrangements in shaping the location and coverage of these systems.

Our study has, however, a few limitations. Characteristics of users were gathered from intercept surveys which may have introduced selection bias and did not allow us to further explore where users lived or whether they owned a private bicycle. Thus, our results may not be considered representative of users of bicycle-sharing systems across Brazil. We were not able to conduct a

ARTICLE IN PRESS

document analysis for all cities. Considering the private partners that manage the greatest number of stations in Sao Paulo also manage the systems in all other cities, findings may be similar and applicable for other Brazilian cities where such bicycle-sharing systems were implemented.

Topography, lower availability, and quality of bicycling infrastructure might also be associated with lower access to these systems in low-income areas, although at the time of systems' implementation in Brazil, bicycling infrastructure was similarly deficient across the cities. In Sao Paulo city, for instance, more than half of the implemented kilometers of cycling paths were implemented after 2014. And yet, the coverage remains low when compared with the entire road network (468 km of cycling paths /17,000 km of street network = 2.8%) (Mobilize Brazil, 2017). Nonetheless, by taking advantage of household travel surveys periodically undertaken in a few large cities (Sá et al., 2016; Zhang et al., 2014), further research could map preferable routes by cyclists to help inform bicycle-sharing systems planners as well as help researchers further tackle inequality issues in accessibility to the systems, particularly to those more willing to use them if connection with other modes of transportation is favorable when sharing stations are chosen (Lovelace et al., 2017; Zhang et al., 2014). Individuals commuting a relatively short distance by individual or public transportation are more likely to shift to bicycle use (Zhang et al., 2014).

Inequality in access to the systems is rooted in the process for choosing the station locations in the city, which was illustrated in greater detail in the case of Sao Paulo; however, further analysis in other cities are warrant. Understanding how bicycle-sharing systems can interconnect and complement trips from other modes of public transportation could reduce such spatial access inequalities and provide valuable information for systems' planners at the public and private sectors. Finally, we considered only spatial accessibility. Understanding individual preferences and barriers that prevent a higher ridership can contribute to a wider assessment of bicycle-sharing systems' users.

In conclusion, we found inequalities in the coverage of bicycle-sharing systems in Brazil, favoring wealthier and centrally located neighborhoods where a comparatively higher proportion of the population is white. Additionally, we showed how contractual arrangements seem to play a greater role than public input in shaping the location and coverage of bicycle-sharing systems in the country. Finally, we found that the bicycle-sharing systems are not necessarily linked to municipal public transportation systems, consequently restricting access for residents who do not live close to the stations' catchment areas.

Acknowledgments

ACD acknowledges funding from the Sao Paulo Research Foundation (2015/19131-3). JDS acknowledges funding from the Sao Paulo Research Foundation (2016/17043-2). LFMR acknowledges funding from the Sao Paulo Research Foundation (2014/25614-4). LMTG acknowledges funding from the National Council for Scientific and Technological Development (402755/2015-4). THS acknowledges funding from the Sao Paulo Research Foundation (2012/08565-4 and 2013/25624-7) and from the National Council for Scientific and Technological Development (200358/2014-6 and 402648/2015-3). We kindly thank Itaú Bank and the Brazilian Center of Analysis and Planning (CEBRAP) for providing access to the data and to the questionnaires. We would also like to thank Isis Ramos for her contribution acquiring the data. The funding sources and the institutions and people acknowledged had no role in the design of this study, data analyses, interpretation of the data, or decision to submit results.

Conflicts of interest

Authors declare no conflicts of interests.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jth.2017.12.011.

References

Abu-Lughod, J.L., 1999. New York, Chicago, Los Angeles: America's Global Cities. University of Minnesota Press, Minneapolis.

Anaya, E., Castro, A., 2012. Balance general de la bicicleta pública en España. Fundación ECA Bureau Veritas e IDAE, Barcelona. 〈https://www.bikesharing.ch/fileadmin/redaktion/bikesharing/Dokumente/Documents_et_autres/Balance_General_Bicicleta_Publica_Espana.pdf〉 (Acessed 19 December 2017).

Balago, R., 2015. Rede de empréstimo de bike em SP pode mudar com fim de convênio — 10/05/2015 - sãopaulo - Folha de S.Paulo. Folha São Paulo.

Banco Central do Brasil, 2015. Top 50 banks by total assets less brokerage [WWW Document]. URL 〈http://www4.bcb.gov.br/fis/TOP50/ingl/Top50I.asp〉 (Accessed 16 May 2017).

Beroud, B., Anaya, E., 2012. Chapter 11 Private Interventions in a Public Service: an Analysis of Public Bicycle Schemes. Transp. Sustain 1, 269–301. http://dx.doi.org/10.1108/S2044-9941(2012)0000001013.

CicloSampa, 2013. . CicloSampa. Bradesco Seguros | Prefeitura de São Paulo | PegBike [WWW Document]. URL 〈http://www.ciclosampa.com.br/〉 (Accessed 17 May 2017).

Clark, J., Curl, A., 2016. Bicycle and car share schemes as inclusive modes of travel? A socio-spatial analysis in glasgow. UK. Soc. Incl. 4, 83–99. http://dx.doi.org/10.17645/si.v4i3.510.

Creswell, J.W., Clark, V.L.P., 2011. Designing and Conducting Mixed Methods Research, 2nd ed. SAGE Publications, Inc, Los Angeles.

de Hartog, J.J., Boogaard, H., Nijland, H., Hoek, G., 2010. Do the health benefits of cycling outweigh the risks? Environ. Health Perspect. 118, 1109–1116. http://dx.doi.org/10.1289/ehp.0901747.

DeMaio, P., Meddin, R., 2017. Bike-Shar. World Map.

Diário Oficial da Cidade de São Paulo, 2015. Memorando GAB.EES. n° 285/2015.

Diário Oficial da Prefeitura de São Paulo, 2016. LEI N° 16.388, DE 5 DE FEVEREIRO DE 2016. Institui o Programa Integra-Bike São Paulo, e dá outras providências.

Diário Oficial da Prefeitura de São Paulo, 2015. Edital de Chamamento Público N° 01/2015-SMT. PROCESSO ADMINISTRATIVO n° 2015-0.121.905-3.

Diário Oficial do Estado de São Paulo, 2013. Celebração do 2° Aditivo do Termo de Cooperação 002/2012/SMT Processo Administrativo n. 2012-0.066.208-0.
Diário Oficial do Estado de São Paulo, 2012. Extrato de Termo de Cooperação. Processo Administrativo n° 2012-0.066.208-0.
Duarte, F., 2016. Disassembling bike-sharing systems: surveillance, advertising, and the social inequalities of a global technological assemblage. J. Urban Technol. 0, 1–13. http://dx.doi.org/10.1080/10630732.2015.1102421.
Duran, A.C., Diez Roux, A.V., Latorre, M., do, R.D.O., Jaime, P.C., 2013. Neighborhood socioeconomic characteristics and differences in the availability of healthy food stores and restaurants in Sao Paulo, Brazil. Health Place 23, 39–47. http://dx.doi.org/10.1016/j.healthplace.2013.05.001.
Embrapa, 2016. A Embrapa - Portal Embrapa [WWW Document]. Empresa Bras. Pesqui. Agropecuária - Embrapa. URL 〈https://www.embrapa.br/〉 (Accessed 17 May 2017).
Fishman, E., Washington, S., Haworth, N., Mazzei, A., 2014. Barriers to bikesharing: an analysis from Melbourne and Brisbane. J. Transp. Geogr. 41, 325–337. http://dx.doi.org/10.1016/j.jtrangeo.2014.08.005.
Gauthier, A., Hughes, C., Kost, C., Li, S., Linke, C., Lotshaw, S., Mason, J., Pardo, C., Rasore, C., Schroeder, B., Treviño, X., 2013. The Bike-share Planning Guide. Institute for Transportation and Development Policy, New York.
Goodman, A., Cheshire, J., 2014. Inequalities in the London bicycle sharing system revisited: impacts of extending the scheme to poorer areas but then doubling prices. J. Transp. Geogr. http://dx.doi.org/10.1016/j.jtrangeo.2014.04.004.
Groat, L.N., Wang, D., 2002. Architectural Research Methods, 1st ed. John Wiley & Sons, New York.
Handy, S., van Wee, B., Kroesen, M., 2014. Promoting cycling for transport: research needs and challenges. Transp. Rev. 34, 4–24. http://dx.doi.org/10.1080/01441647.2013.860204.
Hoffmann, M.L., Lugo, A., 2014. Who is 'world class'? Transp. Justice Bicycl. Policy.
Hunter, D.J., Frumkin, H., Jha, A., 2017. Preventive medicine for the planet and its peoples. N. Engl. J. Med. 376, 1605–1607. http://dx.doi.org/10.1056/NEJMp1702378.
IBGE, 2016. . Instituto Brasileiro de Geografia e Estatística [WWW Document]. Inst. Bras. Geogr. E Estat. Cid. URL 〈http://www.cidades.ibge.gov.br/〉 (Accessed 16 May 2017).
Jaime, P.C., Duran, A.C., Sarti, F.M., Lock, K., 2011. Investigating environmental determinants of diet, physical activity, and overweight among adults in Sao Paulo, Brazil. J. Urban Health 88, 567–581. http://dx.doi.org/10.1007/s11524-010-9537-2.
League of American Bicyclists, 2015. Where We Ride 2014: An Analysis of Bicycling in American Cities.
Lee, I.-M., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N., Katzmarzyk, P.T., 2012. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 380, 219–229. http://dx.doi.org/10.1016/S0140-6736(12)61031-9.
Lovelace, R., Goodman, A., Aldred, R., Berkoff, N., Abbas, A., Woodcock, J., 2017. The Propensity to cycle tool: an open source online system for sustainable transport planning. J. Transp. Land Use 10. http://dx.doi.org/10.5198/jtlu.2016.862.
Markusen, A., 2004. The work of forgetting and remembering places. Urban Stud. 41, 2303–2313. http://dx.doi.org/10.1080/00420980412331297546.
Meddin, R., 2017. The bike-sharing world at the end of 2016. Bike-Shar. Blog.
Mobilize Brasil, 2017. Mobilize Brasil. URL 〈http://www.mobilize.org.br/estatisticas/〉 (Accessed 04 Jan 2018).
Mobilize Brasil, 2016. Entrevista: Os planos do Itaú para as bicicletas em 2017 [WWW Document]. URL 〈http://www.mobilize.org.br/noticias/10063/itau-fara-upgrade-nas-bikes-compartilhadas-do-pais-em-2017.html〉 (Accessed 16 May 2017).
Mobilize Brasil, 2013. SP terá novo sistema de aluguel de bicicletas a partir de domingo [WWW Document]. URL 〈http://www.mobilize.org.br/noticias/5524/sp-tera-novo-sistema-de-aluguel-de-bicicletas-a-partir-de-domingo.html〉 (Accessed 16 May 2017).
Mobilize Brasil, 2012. Prefeito pedala e inaugura Bike Sampa [WWW Document]. URL 〈http://www.mobilize.org.br/noticias/2140/bike-sampa.html〉 (Accessed 16 may 2017).
NACTO, 2016. Bike share station siting guide.
Ogilvie, F., Goodman, A., 2012. Inequalities in usage of a public bicycle sharing scheme: socio-demographic predictors of uptake and usage of the London (UK) cycle hire scheme. Prev. Med. 55, 40–45. http://dx.doi.org/10.1016/j.ypmed.2012.05.002.
Olds, K., 2002. Globalization and Urban Change: Capital, Culture, and Pacific Rim Mega-Projects. Oxford University Press, U.S.A., Oxford.
QGIS Development Team, 2017. QGIS Geographic Information System. Open Source Geospatial Foundation.
Ragin, C.C., Amoroso, L.M., 2010. Constructing Social Research: The Unity and Diversity of Method, 2nd ed. SAGE Publications, Inc, Los Angeles.
Ricci, M., 2015. Bike sharing: a review of evidence on impacts and processes of implementation and operation. Res. Transp. Bus. Manag. Manag. Bus. Cycl. 15, 28–38. http://dx.doi.org/10.1016/j.rtbm.2015.03.003.
Rojas-Rueda, D., de Nazelle, A., Tainio, M., Nieuwenhuijsen, M.J., 2011. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. BMJ 343. http://dx.doi.org/10.1136/bmj.d4521.
Romanillos, G., Austwick, M.Z., Ettema, D., Kruijf, J.D., 2016. Big data and cycling. Transp. Rev. 36, 114–133. http://dx.doi.org/10.1080/01441647.2015.1084067.
Sá, T.H., Duran, A.C., Tainio, M., Monteiro, C.A., Woodcock, J., 2016. Cycling in São Paulo, Brazil (1997–2012): correlates, time trends and health consequences. Prev. Med. Rep. 4, 540–545. http://dx.doi.org/10.1016/j.pmedr.2016.10.001.
Shaheen, S., Cohen, A., Zohdi, I., 2016. Shared Mobility: Current Practices and Guiding Principles. U.S. Department of Transportation Federal Highway Administration, Washington, D.C.
Shaheen, S.A., Martin, E.W., Cohen, A.P., 2013. Public Bikesharing Modal Shift Behav.: A Comp. Study Early Bikesharing Syst. North Am.
Shatkin, G., 2008. The city and the bottom line: urban megaprojects and the privatization of planning in Southeast Asia. Environ. Plan. A 40, 383–401. http://dx.doi.org/10.1068/a38439.
Small, A., 2017. 4 reasons why seattle's bike share failed. CityLab.
Soares, R., 2016. Sistema BikePE está sucateado. Faltam bicicletas e falhas são cada vez mais frequentes [WWW Document]. UOL – Olho No Trânsito. URL 〈http://jc.ne10.uol.com.br/blogs/deolhonotransito/2016/11/23/sistema-bikepe-esta-sucateado-faltam-bicicletas-e-falhas-sao-cada-vez-mais-frequentes/〉 (Accessed 17 May 2017).
Tainio, M., de Nazelle, A.J., Götschi, T., Kahlmeier, S., Rojas-Rueda, D., Nieuwenhuijsen, M.J., de Sá, T.H., Kelly, P., Woodcock, J., 2016. Can air pollution negate the health benefits of cycling and walking? Prev. Med. 87, 233–236. http://dx.doi.org/10.1016/j.ypmed.2016.02.002.
The World Bank, 2016. World Development Indicators | DataBank [WWW Document]. URL 〈http://databank.worldbank.org/data/reports.aspx?Source=2&series=SI.POV.GINI#〉 (Accessed 10 September 2017).
Toole Design Group, 2012. Bike Sharing in the United States: State of the Practice and Guide to Implementation. U. S. Department of Transportation – Federal Highway Administration.
United Nations, 2017. Resolution 71/256, New Urban Agenda, A/RES/71/256. United Nations.
Villaça, F., 2011. São Paulo: segregação urbana e desigualdade. Estud. Av. 25, 37–58. http://dx.doi.org/10.1590/S0103-40142011000100004.
Watson, K.B., Carlson, S.A., Humbert-Rico, T., Carroll, D.D., Fulton, J.E., 2015. Walking for transportation: what do U.S. adults think is a reasonable distance and time? J. Phys. Act. Health 12, S53–S61. http://dx.doi.org/10.1123/jpah.2014-0062.
Weiss, R.S., 1995. Learning From Strangers: the Art and Method of Qualitative Interview Studies. Simon & Schuster, New York.
Wild, K., Woodward, A., Field, A., Macmillan, A., 2017. Beyond 'bikelash': engaging with community opposition to cycle lanes. Mobilities 0, 1–15. http://dx.doi.org/10.1080/17450101.2017.1408950.
Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., Goodman, A., 2014. Health effects of the London bicycle sharing system: health impact modelling study (g425–g425). BMJ 348. http://dx.doi.org/10.1136/bmj.g425.
Yeoh, B.S.A., 1999. Global/globalizing cities. Prog. Hum. Geogr. 23, 607–616. http://dx.doi.org/10.1191/030913299674647857.
Yin, R.K., 2008. Case Study Research: Design and Methods, Fourth ed. SAGE Publications, Inc, Los Angeles, Calif.
Zhang, D., Magalhães, D.J.A.V., Wang, X. (Cara), 2014. Prioritizing bicycle paths in Belo Horizonte City, Brazil: analysis based on user preferences and willingness considering individual heterogeneity. Transp. Res. Part Policy Pract. 67, 268–278. http://dx.doi.org/10.1016/j.tra.2014.07.010.